Educational Series No. 4

PENNSYLVANIA GEOLOGY SUMMARIZED

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
Genevieve Blatt, Secretary

TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

EDUCATIONAL SERIES No. 4

PENNSYLVANIA GEOLOGY

Summarized . . .

by Bradford Willard

PREFACE

This pamphlet was originally published by the Pennsylvania Geological Survey in 1935 as Progress Report 113. Through the years a number of revisions were made both by the author and by the Survey Staff. This edition, now published as Educational Series no. 4, presents the basic text with several additions and with all of the illustrations being wholly new or modified by the staff of the Geological Survey.

INTRODUCTION

The purpose of this bulletin is to provide our science teachers and other interested Pennsylvanians with basic geologic information in general and on Pennsylvania in particular. For this purpose the bulletin is divided into two parts. The first part deals with the outstanding principles of the science; the second summarizes the geology of the State.

BASIC PRINCIPLES OF GEOLOGY

Geology is the study of the earth, particularly the earth's crust. Geology is not so much one distinct science, as a group of closely related sciences. It is unnecessary to define or even mention all of these branches, but we should have a basic conception of the more important ones and likewise understand some of the terms that are in common use among geologists.

The most obvious branch of geology is physiography (or geomorphology). It as an amplification of the physical geography of our school days, for it describes the surface features of the earth, its mountains, plains, valleys, streams, lakes and oceans and tries to understand the origin of these features, Physiography treats of the agencies of nature which modify the earth's surface, most spectacular of which are moving air (wind), water (currents and waves), and ice (glaciers). Many other chemical as well as physical forces change the landscape. Thus, weathering and erosion or rock destruction and removal respectively may be physical or chemical. Physiography is simply geology in action. From the surface characters of the earth we may turn to the composition of its crust.

Mineralogy, as its name implies, is the study of minerals. Despite their common occurrence, a good definition of a mineral is hard to write, but we may look upon them as inorganic substances (formed independent of life) which occur in nature (this eliminates inorganic products of the chemical laboratory) and usually are crystalline in form, having definite chemical and physical properties. Many minerals, particularly those in part or wholly metallic, are of value to man and are mined as ores. There are also nonmetallic earth-products such as coal, petroleum and limestone which are indispensable to

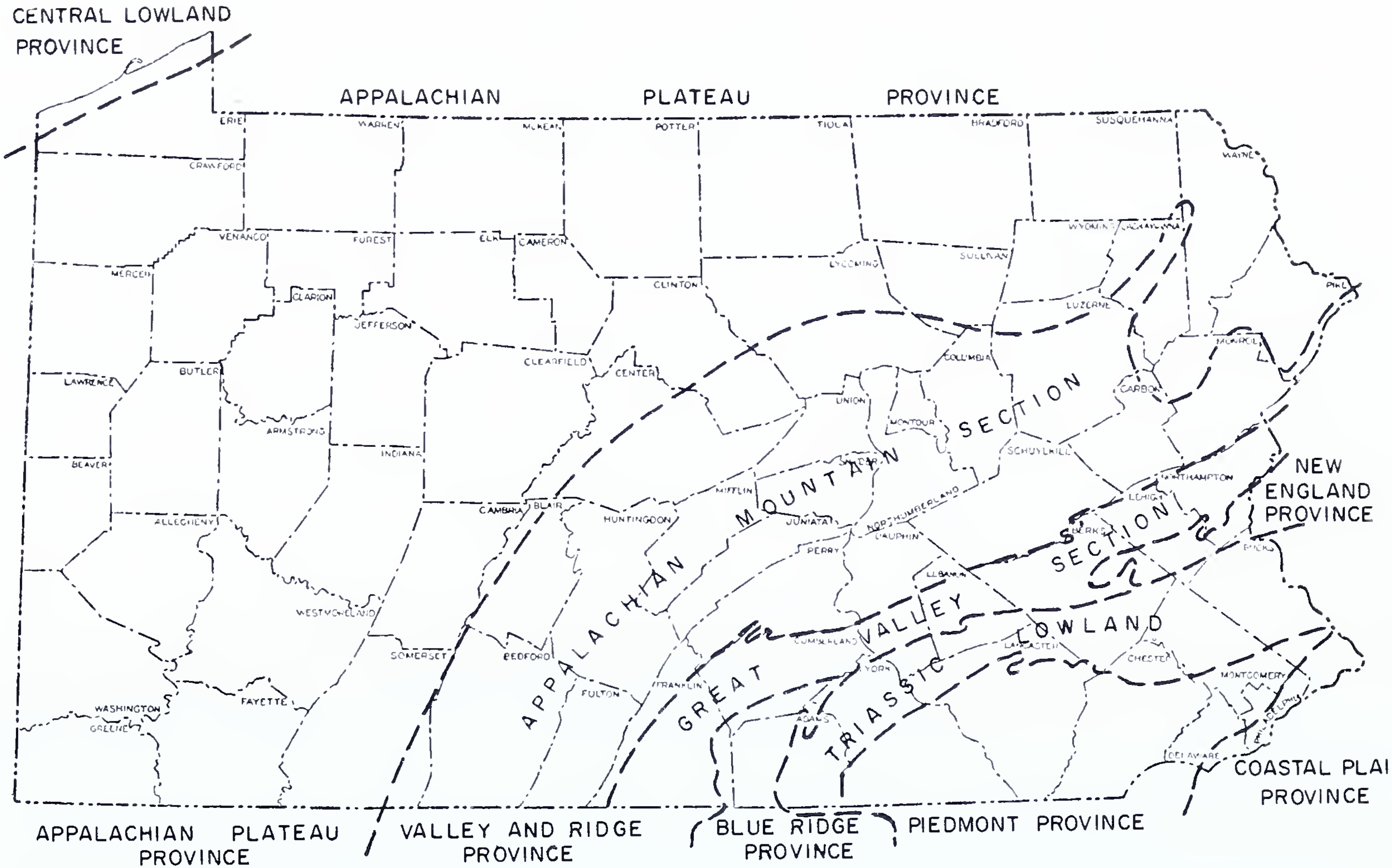


Figure 1. Physiographic Divisions of Pennsylvania

civilization. The study of the occurrence and the search for these substances is termed economic geology. When one or more minerals form an appreciable portion of the earth's crust, the aggregate is called a rock; and the branch of geology which deals with the origin, character and composition of rocks is called petrology.

The areas in which different types of rocks are found in Pennsylvania are shown on the Geologic Map of Pennsylvania in the center of this booklet. Rocks on this map are grouped by their age, the different ages being shown in the explanation at the bottom of the map. Under each box are listed the major types of rock which occur in Pennsylvania. Also listed are the important rock and mineral products which have been mined or quarried for each age rock. This map, like the text of the booklet, is a summary of the State's rocks.

Rocks are of three great classes or groups distinguished according to their mode or origin. They vary greatly in physical and chemical character. We have been familiar from childhood with stories of volcanic eruptions in which streams of melted rock called lava flow from crater-topped mountains, bringing desolation to any living thing in their courses. Cold, solidified lava exemplifies a large and diverse group of rocks which have similarly cooled and solidified from a hot, fluid state. This group includes such common examples as granite, some of the "trap" rocks of commerce, and pumice stone. Because such rocks are "fire-born", they are called igneous rocks. Igneous rocks are usually even grained with little or no banding of their crystalline, mineral constituents. When the minerals that compose them can be seen, we find them scattered helter-skelter through the mass. But even the hardest granite may weather to sand and mud. We may see this process going on in ledges exposed to the wind and the rain, the frosts of winter and summer suns. This mud and sand, transported elsewhere, become sediments. When laid down in the beds of streams or lakes or the ocean bottom these sediments may in time be hardened into sedimentary rocks. The sedimentary rocks are the second great class. They are usually recognized by their bedded or stratified habit, each bed commonly composed of grains derived from older, broken-up rocks. There are many kinds of sedimentary rocks; we need mention only four: (1) shale, indurated (hardened)

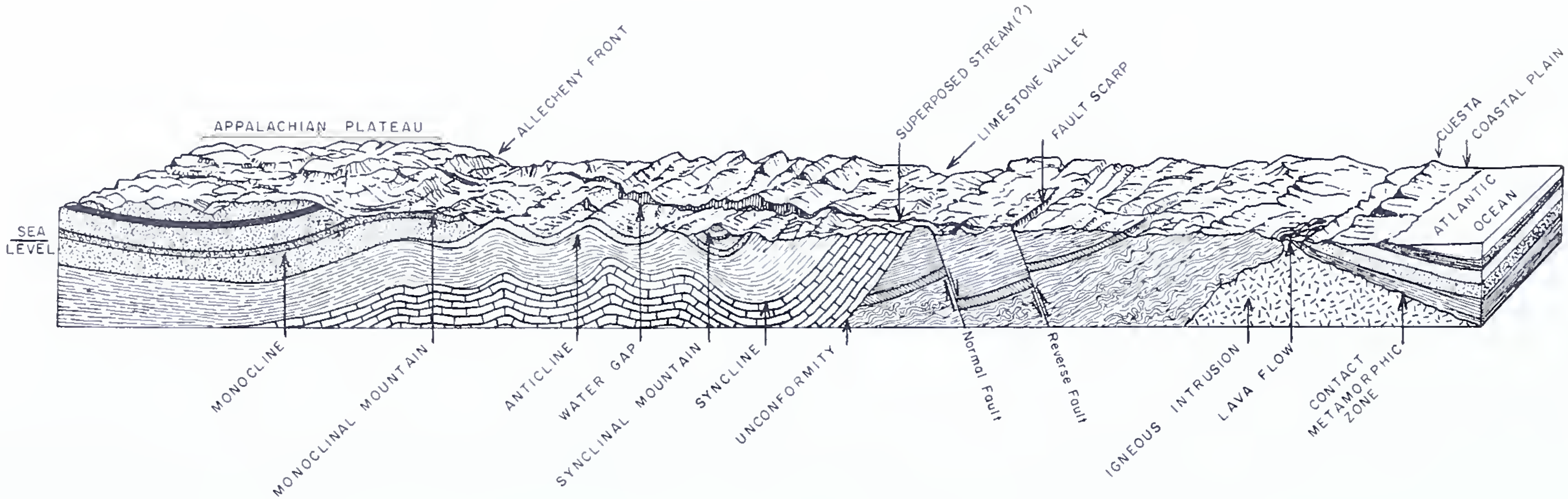


Figure 2. Idealized Block Diagram across Pennsylvania showing Geologic Structures and their Relation to Topography

mud, (2) sandstone made up of cemented sand grains, (3) conglomerate which is consolidated gravel, and (4) limestone, a rock consisting largely of carbonate of lime ($CaCO_3$). Limestone, unlike the other three kinds of sedimentary rocks, is not formed of fragments of older rocks, but consists of material derived by solution from weathered, older rocks. Circulating water under favorable conditions is an important dissolving agent. From such solution dissolved carbonate of lime may eventually be precipitated. The third and last class of rocks is formed directly from either the igneous or sedimentary groups by a process of change brought about chiefly by the application of heat and pressure. Because of having undergone such a metamorphosis, this third class is called the metamorphic rocks. The character of the parent rock may be partly or wholly changed; the altered products include such well-known substances as marble, serpentine and slate. Metamorphic rocks are often foliated; that is, they split into thin layers which are in no way related to stratification. Close examination may show that the minerals of these rocks are aligned in rows, layers, or bands parallel to the direction in which the rock breaks (called rock cleavage).

We saw that the metamorphic rocks owe their origin largely to the effect of forces acting upon other, older rocks. The study of these forces is called dynamic geology. This teaches us that rocks may be folded and broken in almost any conceivable manner. Such displacements are called geologic structures. Their study is structural geology. Of the many kinds of structures recognized, we may confine ourselves to two general types. Where the rocks are bent the curved portion becomes a fold. If the rocks break and adjacent parts move in relation to one another along the fracture, we speak of such a structure as a fault. Figure 2 illustrates the commonest kinds of folds and faults.

Up-folded strata are called an anticline and down-folded strata a syncline. If the strata are bent in a simple flexure dipping in one direction, the structure is a monocline. Faults are of two kinds. A normal fault is one formed by tension, and it lengthens the earth's crust at the fault. It may be identified by the fact that the surface slopes in the direction of the downthrown side. A reverse or thrust

fault is formed by compression, shortens the earth's crust at the fault, and may be identified by the fault "plane" dipping in the direction of the upthrown side. Figure 2 also shows different kinds of rock and their relation to one another.

The study of the sedimentary rocks involves other branches of geology. Stratigraphy and sedimentation treat of their origin and history. Sedimentary rocks contain remains of the plants and animals which lived in the region when a particular deposit was made. Such remains are chiefly hard parts of organisms preserved more or less intact. They are called fossils. Fossils are absent from igneous rocks; no life could have existed in those molten masses. They are very rare in metamorphic rocks; for, even were the parent rock a sediment, the very processes which metamorphosed it tended simultaneously to obliterate all signs of life. Fossils are of many sorts and tell such significant stories of the past life on the earth that they have been called "the documentary evidence of evolution". The science which treats of ancient life on the earth is called paleontology.

Through paleontology and stratigraphy we study earth history or historical geology. Because the fossil-bearing strata were deposited one upon another, the lower ones are the oldest and contain the remains of the more primitive life forms. Where vast thicknesses of sediments have accumulated, we are sometimes able to observe the entire succession if the rocks have been folded or faulted, raised and dissected by erosion, as in our mountainous regions.

Earth history bears analogies to human history. Both have their modern, medieval and ancient divisions, and in each the ancient history is preceded by a long, prehistoric interval whose beginning is lost and whose events are obscurely known. Both human and earth histories have had their times of tranquility and of upheaval and revolution. We see in each a succession of ruling dynasties of the living which rise, flourish and fall before their successors. A major division of earth history is spoken of as an era. Each era is represented by vast thicknesses of sedimentary rocks enclosing fossil remains of distinctive, contemporaneous life forms. Because of these remains, the eras are given names indicating their dominant life forms. The Cenozoic era is camparable to modern history of man,

and the Mesozoic and Paleozoic respectively to medieval and ancient histories. The Proterozoic and Archeozoic eras are analogous to human prehistoric time. Each era is separated from the adjacent by times of geologic revolution. A geologic revolution is not like the sudden overthrows of human history, but is an infinitely long interval, during which mountain making takes place as the crust is here and there thrown into folds. Igneous rocks rise from below and cut through the sediments to escape at the surface; or, invading those same bedded rocks below the surface produce metamorphic changes in them. Each revolution is a time of accelerated evolution. With surface alterations come climatic changes and consequent extinction of some and adaptation of other races of plants and animals to the new environments. The eras are themselves chronologically divided into periods each represented by its own succession of rock groups and formations called a system. We need not trouble ourselves with the origin of the period names, beyond stating that they are usually taken from some locality where rocks of the corresponding system are characteristically developed. In the strata of each system are buried fossils, some of which at least represent kinds of life which flourished only during the corresponding period. By their distinctive fossils the rocks of different ages may be recognized over wide areas. Such diagnostic fossils are called guide or index fossils. The periods are separated by disturbances, analogous to but less consequential and shorter lived than the revolutions. The succession of periods and eras has been tabulated in the geologic timetable on the back cover. Recognized rocks for every period except the Jurassic occur in Pennsylvania.

Besides working out the geologic time divisions, historical geology has another important function. It tries to picture the physiography and geography of the ancient world. We have learned that our mountains may occupy regions of ancient sea bottoms; and that vast, shallow seas have flooded large parts of the continents. Fossils of marine shells are known from the high Alps, and the teeth and bones of land mammals have been dredged from the present sea floor far from land.

"There rolls the deep where grew the tree.
Oh, earth what changes hast thou seen!
There where the long street roars has been
The stillness of the central sea."

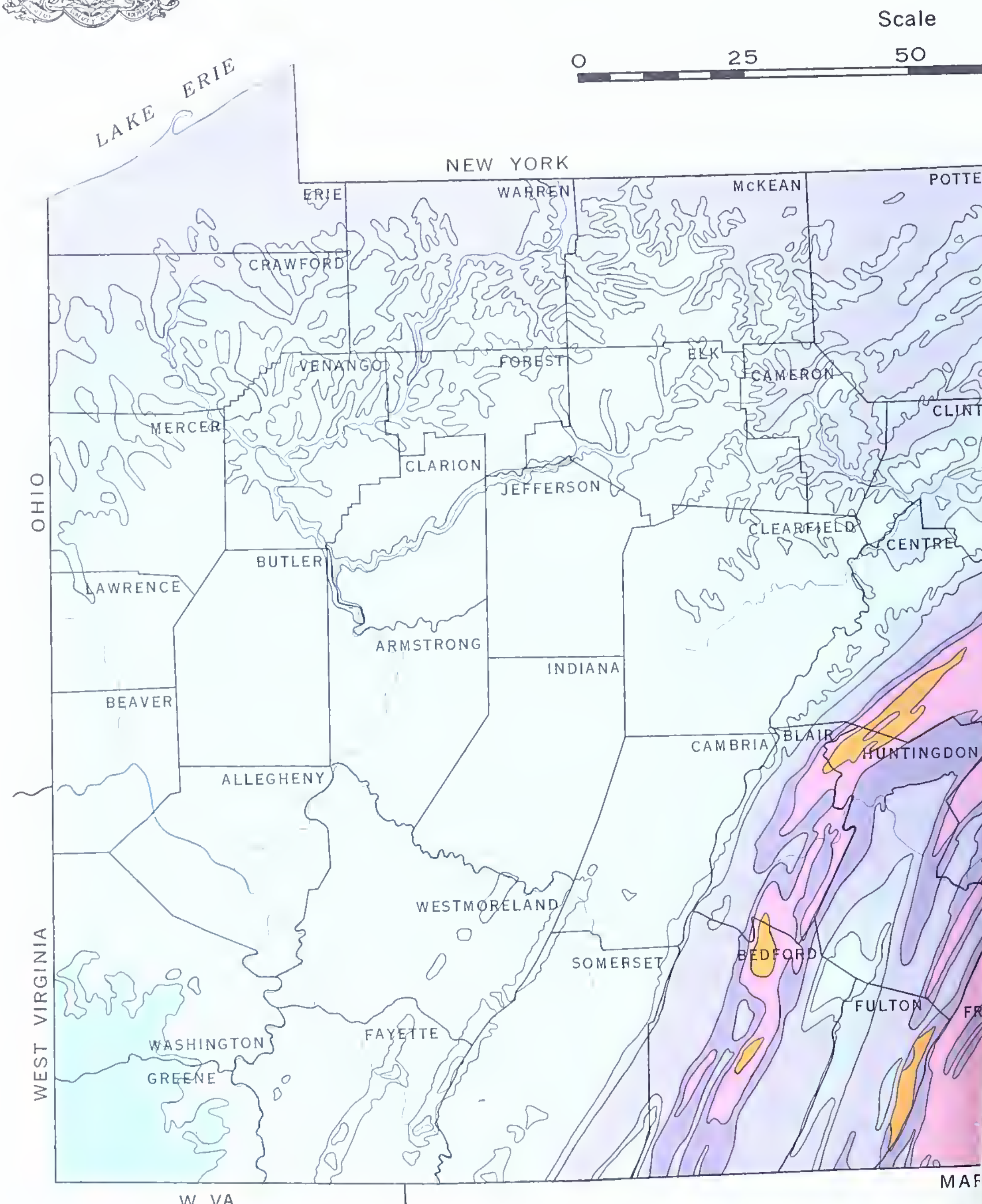
Historical geology is intimately connected with the questions of the age of the earth. We cannot here discuss the methods whereby chronologic data are obtained, nor is it germane to enumerate the lengths of the several eras and periods. Suffice it to say that these are far from being of uniform length; for the entire post-Mesozoic time, for example, is approximately of equal length to the Ordovician period alone of the Paleozoic era. Some suggestion of the immensity of geologic time may be gathered if we note merely that the Cenozoic era began about 65,000,000 years ago, the Mesozoic some 230,000,000 years ago, and the Paleozoic era dawned a little over half a billion years before the present. The portion of known geologic time prior to the Cambrian period (spoken of collectively as the Precambrian) is longer than all the succeeding eras combined. From the foregoing summary of basic, geologic principles, we must admit that geology is complex. It is for this very reason closely related to other sciences.

Some appreciation of the intimacy of such relations may be had if one observes the list of non-geologic studies which are found today in the college curricula prescribed for students of geology. They include such subjects as chemistry, physics, biology, mathematics, engineering, and economics. Conversely, the interests of many fields of modern science and other branches of study interfinger with geology.

THE ROCKS OF PENNSYLVANIA

As we turn from the geologic resume of Part I to the geology of Pennsylvania, we are confronted with a story so long and ramified that an attempt even to summarize it thoroughly would require far more space than can be here allotted. We must confine ourselves to describing the age and character of the larger stratigraphic units, to defining the principal surface features, and to telling concisely the geologic history of the State.

GEOLOGIC MAP OF PEN



QUATERNARY
(0-1 million yrs.)
Sand and gravel.
sand and gravel.

TRIASSIC
(180-230 mil. yrs.)
Shales and sandstones intruded by diabase. (red)
iron, building stone.

PERMIAN
(230-280 mil. yrs.)
Cyclic sequences of sandstone, red beds, shale, limestone, and coal.

PENNSYLVANIAN
(280-310 mil. yrs.)
Cyclic sequences of sandstone, limestone, shale, clay, and coal.
coal, clay, lime.

MISSISSIPPIAN
(310-350 mil. yrs.)
Red beds, shale, and sandstone.

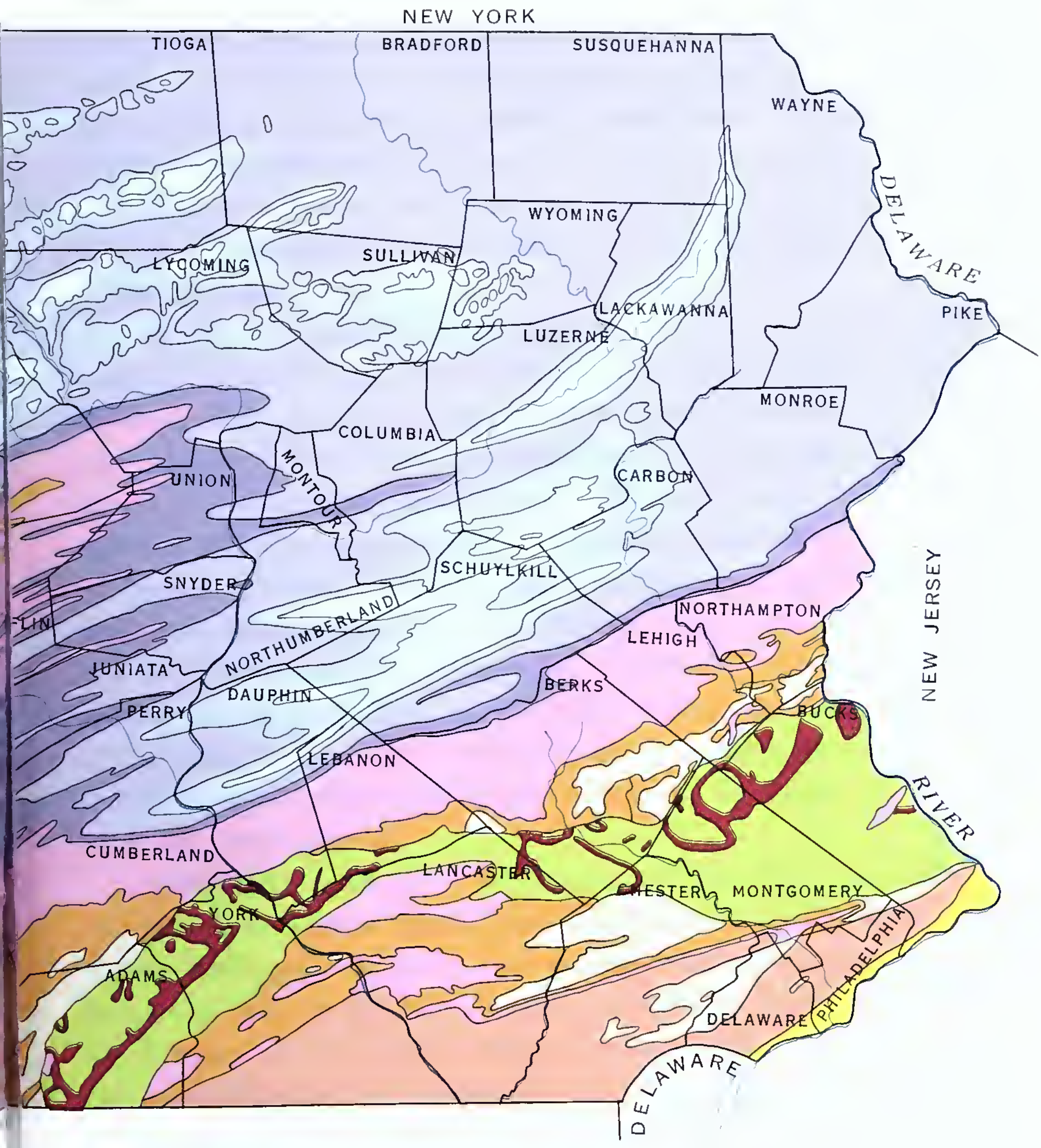
DEVON
(350-400 mi
Red beds,
sandstone,
stone and
silica san

NSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
GENEVIEVE BLATT, *Secretary*

TOPOGRAPHIC AND GEOLOGIC SURVEY
ARTHUR A. SOCOLOW, *State Geologist*

75 100 miles



SILURIAN
(4-425 mil. yrs.)
...lstone, red
... shale, and
... tone.
...ister, lime.

ORDOVICIAN
(425-500 mil. yrs.)
Shale, limestone, dolomite, sandstone.
slate, limestone, zinc.

ORDOVICIAN and / or CAMBRIAN
(425-600 mil. yrs.)
Metamorphic rocks-schist, serpentine, gneiss and quartzite.
Building stone.

CAMBRIAN
(500-600 mil. yrs.)
Limestone and dolomite; some sandstone and shale.
lime and gannister.

PRECAMBRIAN
(Older than 600 mil. yrs.)
Gneiss, greenstone, serpentine and anorthosite.
zinc, building stone, graphite, serecite.

Geologic systems in Pennsylvania. Pennsylvania, though comparatively poor in igneous and metamorphic rocks, possesses widespread sedimentary formations thousands of feet thick and assignable to at least ten systems. All of these usually continue to regions beyond the borders of the State. The succession may be visualized as layer upon layer of rock spread one above another over a greater or less part of the State. Folding, tilting, faulting and uplift, followed by deep cut erosion, have exposed the older beds. Because the intensity of these processes decreases in a northwesterly direction, it may be said that in general as we traverse Pennsylvania from the southeast toward the northwest we encounter, with few exceptions, successively younger rocks.

In the extreme southeastern portion of Pennsylvania in southeastern Bucks County and extending across Philadelphia, Delaware, Chester, and southern Lancaster and York Counties, is a band of ancient, crystalline (that is, chiefly metamorphosed) rocks. There is some disagreement among geologists as to just which system or systems are represented here, the difficulty being in part due to lack of fossils. Probably some of these formations belong to the older Paleozoic systems (Cambrian and Ordovician), but others are doubtless still more ancient and may be assigned to the Precambrian as among the oldest rocks of the State. Unquestioned Precambrian rocks occur also in the core of South Mountain through southern Northampton, Lehigh and Berks Counties, in Adams County, and at a few other places.

Sandstones and other sediments of Cambrian age have been recognized in narrow bands from southern Bucks County to Adams County and again about the flanks of the South Mountains. The great limestone belts in the Lehigh and Cumberland Valleys and also isolated areas of these same rocks in Centre, Huntingdon, Blair and Bedford Counties are in part Cambrian in age but chiefly belong to the Ordovician system. The slates of Lehigh and Northampton Counties and, westward, the contemporaneously formed shales above the limestone just mentioned are also assigned to the Ordovician. With few exceptions, our Cambrian and Ordovician rocks are deficient in fossils.

Stretching southwestward across the State from the Delaware Water Gap is First or Kittatinny Mountain, which is composed of very hard Silurian sandstone and conglomerate. These same rocks are responsible for many of the long, even-crested, mountain ridges that zigzag through central Pennsylvania. Additional Silurian rocks follow these ridge makers. Because they are of softer materials they usually underlie valleys which parallel the ridges. Overlying the Silurian rocks are the thick sandstones and shales and a few thin limestones belonging to the Devonian system. These are found everywhere separating the Silurian strata from the formations of the Mississippian system which immediately underlie our coal measures, The Devonian formations extend from the Upper Delaware Valley southwestward into central Pennsylvania, next to the terrain occupied by the Silurian system. Both the Silurian and Devonian strata are as a rule highly fossiliferous, in sharp distinction from the Cambrian and Ordovician, but throughout all four of these systems the fossils are nearly all those of marine invertebrates.

The Mississippian, Pennsylvania, and Permian systems collectively are sometimes referred to as the "Carboniferous", a convenient term when details are unessential. The name comes from the fact that these systems include the chief coal-producing beds of the world. Unlike the preceding systems, which are mostly marine sediments, the "Carboniferous" rocks of Pennsylvania are principally fresh-water beds laid down on the continent inland from the sea. They consist for the most part of gray sandstones, shales, and conglomerates: and the middle portion (Pennsylvania system) contains those extensive coal beds for which our Commonwealth is justly renowned and for which reason its name is applied to this division. Throughout these rocks of late Paleozoic age the commonest fossils are the remains of land plants. The "Carboniferous" marks the close of the Paleozoic sequence, but younger rocks are known in Pennsylvania.

Across the southeastern region from Bucks County to Adams County is a band made up of thousands of feet of beds of sandstone, shale and conglomerate, most of which are red. These are the Triassic strata and like the "Carboniferous" were deposited in fresh water, but their red color and the absence of coal imply that somewhat

different but not fully understood climatic conditions prevailed in Mesozoic than in late Paleozoic time. Fossils are scarce, but plant impressions and foot tracks of reptiles, the dinosaurs, are occasionally found in the shales. Mesozoic rocks other than the Triassic are not surely known in Pennsylvania unless we except small patches of supposed Cretaceous sediments in Montgomery and Chester Counties. No sure Tertiary rocks are known, but the closing event of the Cenozoic era, the great Quaternary (or Pleistocene) ice invasion of North America, is recorded in Pennsylvania in thick, ice-laid deposits of unconsolidated mud, sand and boulders and in loose sediments left by water running out from the melting ice. These are confined chiefly to the northeastern and northwestern corners of Pennsylvania. A small area of marine sand and gravel of Pleistocene or later age belonging to the Atlantic coastal plain sediments occur in the region of Philadelphia.

Except for the metamorphic rocks in southeastern Pennsylvania all the formations so far described are sedimentary. But igneous rocks are recognized. Ancient ones cut into the Precambrian and some of the older Paleozoic formations as if crustal cracks had opened and let imprisoned lavas well up through the sediments. Much younger bodies of igneous rock, called "trap", cut through the Triassic red beds in all directions and at every angle and even extend far beyond their limits into older terrain.

Physiographic features. Mountains trending northeast-southwest resolve the surface features of our State into three clearly defined regions which are in turn composed in part of lesser units. These features are usually the direct result of geologic structures, but some depend also upon the kinds of rock from which they have been etched. Still other factors have helped to modify the surface expression.

Northwest of a gently sinuous line drawn roughly from Wayne County to Somerset County is the Appalachian Plateau. See Figure 1. It is a land characterized by high, flat-topped divides separated by steep-sided valleys in which flow deeply entrenched streams. In the northern part of this region, which was glaciated, the effect of the ice is noticed in profoundly altered scenery. The rocks beneath the

plateau are a fairly uniform succession of "Carboniferous" and Devonian sediments and have suffered little folding or faulting. Rather, they were raised bodily to or above their present elevation. It is chiefly because of these two factors, uniformity of sediments and the horizontal attitude of the strata, that the high plateaus are what they are today.

Immediately east and south of the plateau country is a region in sharp contrast with the foregoing. This is the broad band of long, narrow mountain ridges and intermontaine valleys known as the Appalachian Mountain Section which crosses the State from the south-central border nearly to the northeast corner. Intense crumpling of the rocks, which are of many kinds of sediment of unequal hardness, was followed by uplift. Subsequent erosion cut valleys in the soft beds and left the hard strata as ridges.

Immediately southeast of the mountainous area lies the Great Valley Section, which also runs diagonally southwest-northeast from Franklin County to Northampton County. It is the great limestone valley and ties in with the Shenandoah Valley. The true Older Appalachian Mountains of the Southern Atlantic States are represented in Pennsylvania by a small, mountainous patch in eastern Franklin, Cumberland and western Adams Counties and a second, similar area extending east from Reading to the Delaware River. Southeast of these mountains is the Triassic Lowland consisting of small ridges and valleys underlain by the red, Triassic sediments. The remainder of the southeastern corner of Pennsylvania is made up of narrow limestone valleys and the low hills of the Piedmont region. Along the extreme eastern edge of the Piedmont, a narrow strip of Coastal Plain is continuous with that prominent feature of the Middle Atlantic States.

Geologic history. Because we are now familiar with the salient features of the succession of the geologic systems and with the physiographic aspect of Pennsylvania, we may turn to a condensed description of how these things came to be. As very little is known of the Precambrian events of Pennsylvania, we shall begin our story of the geologic history with the Cambrian period and interpret our story from what we can see in the rocks of the State.

During much of Paleozoic time the general relations of land and sea in the eastern part of the United States were nearly opposite to those of today. Southeastern Pennsylvania was then part of the border of a great, eastward-extending, continental land mass, Appalachia, composed of Precambrian metamorphic and igneous rocks. Its western shore crossed southeastern Pennsylvania; and, westward thereof, a vast sea spread into the interior of North America. Along the coast of Appalachia in Cambrian time were sandy beaches. Farther out from shore (to the west) were laid down muds and limy oozes. In Ordovician time the sea spread farther eastward. overwhelming the earlier Cambrian beaches and covering many of the areas of ancient crystalline rocks of Appalachia. Thousands of feet of lime carbonate now seen in the great limestone valleys were deposited. The limy beds were followed by hundreds of thousands of feet of mud destined to become shale and in part the slate of eastern Pennsylvania. The Ordovician ended in time of change. The ancient land rose and the seas withdrew northwestward. The Ordovician and Cambrian sediments were squeezed by a force exerted from the southeast. The shales, limestones and sandstones suffered changes and, in the east, were folded. Upon these beds were spread a thousand or more feet of debris washed into the borders of the sea from the newly raised land to the east. These coarse sediments became the Silurian sandstones and conglomerate of Kittatinny Mountain and other ridges of central Pennsylvania. After the first uplift comparative quiet continued during Silurian and Devonian times. Much of southeastern Pennsylvania probably remained dry land, while over the rest of the State a thick succession of sandstones, shales and an occasional thin limestone accumulated. Most of these beds formed in shallow water. Because their aggregate thickness is thousands of feet, we assume that the ocean bottom gradually subsided as the sediments accumulated.

Toward the end of the Devonian came renewed uplift of the eastward land-mass, Appalachia, so that the quickened (steepened) streams of that region flowing westward to the interior sea carried in a tremendous quantity of material which brought the ocean bottom up to sea level and created much dry land. The coarse-grained sediments of this time formed massive sandstones that later became

the basis of many of our mountains and the high plateaus of northern Pennsylvania. During the Mississippian Period that followed, the seashore extended across western Pennsylvania, so that most of the deposits were laid down upon a broad coastal land area. This deposition was interrupted by long periods in which part or all of the State was subject to erosion. Then came the Coal Measures of the Pennsylvanian and Permian periods, with most of the State alternately just at or a little above or below sea level, so that cyeles of beds were repeated many times. Part of the time vast swamps spread over the State and later became coal beds.

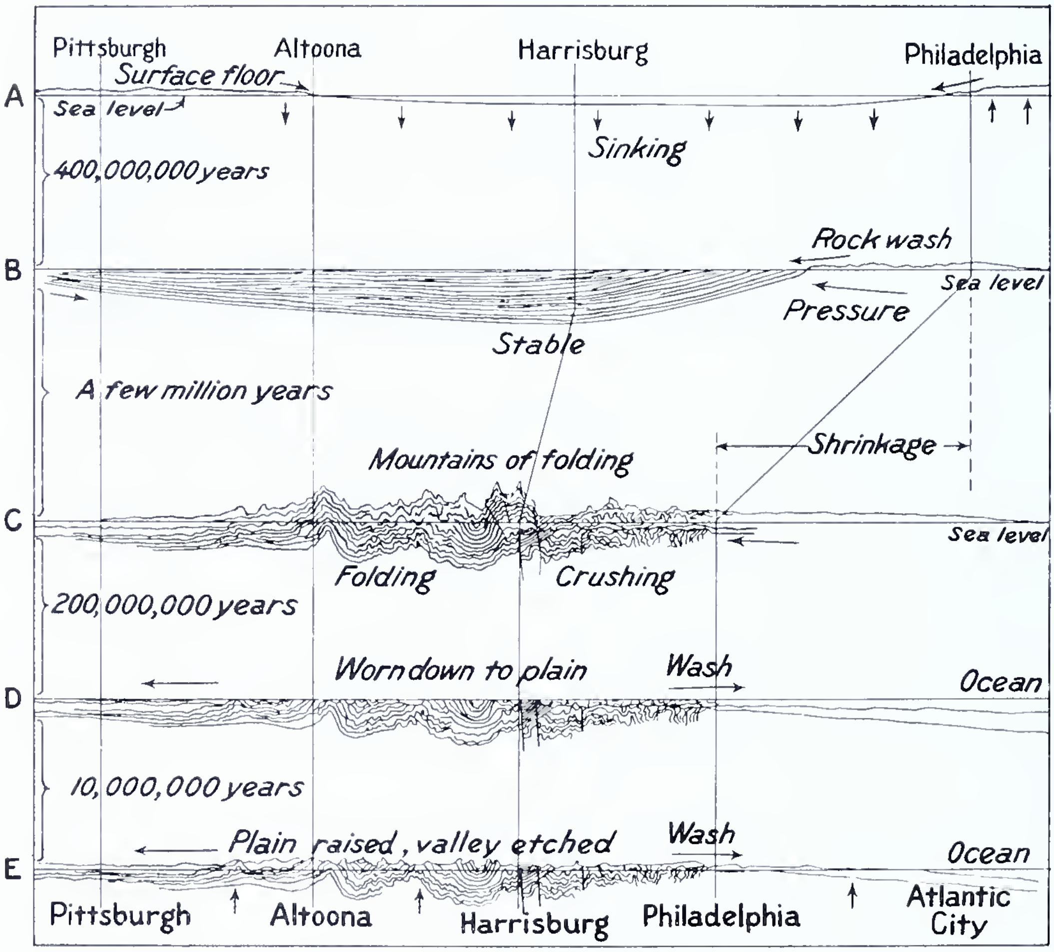


Figure 3. Sketch showing Stages in the Geologic Development of Pennsylvania

The Appalachian Revolution closed the Paleozoic era and great pressure from the southeast folded the thousands of feet of rocks as one might wrinkle a pile of blankets by pushing on one end. At the southeast, the rocks were pushed into an indescribable jumble; between Harrisburg and Altoona, great folds miles high were formed. This folding left some rocks of central Pennsylvania standing more or less vertically. Here and there the folds broke and one side was shoved across the other side. In western Pennsylvania folding became gentle and died out.

When the pressure was relieved, the crust at the east under the old land mass collapsed or subsided to form a long trough across southeastern Pennsylvania. Into this fault-cut lowland streams brought sediments. which piled up thousands of feet in thickness in Triassic time. Eventually, outpourings of lava cut through these strata, forming the trap rocks of southeastern Pennsylvania.

For a long time after the folding, Pennsylvania was part of a great land mass slowly wearing down. Ultimately it wore down to a nearly level plain called a peneplain. At first, during the Triassic and Jurassic periods, the land mass included most of North America. In Cretaceous time the edges of this land mass subsided and sediments were deposited on its eastern and southern edges. Whether any of Pennsylvania was at one time covered by such sediments is not certain. Probably as sinking took place on the edges there was some uplift in the center.

Cretaceous time, the last of the Age of Reptiles, was followed by the Tertiary or Age of Mammals. During most of this time, Pennsylvania was probably a land of low relief, rising steadily as the edges of the land mass still subsided, and received sediments of Tertiary Age to the east and south. Only small traces of these sediments remain in Pennsylvania, capping the divides in the Philadelphia area. In late Tertiary time, uplift became more rapid. The streams, which previously had kept the land surface worn down to a nearly level plain, began to deepen their channels. Uplift centered across the State in a north-south line through Altoona. As uplift and channel sinking continued, the belts of softer rocks were etched out

into valleys. The main streams kept their courses down the slopes of the rising land, cutting deep notches across the harder strata. During the process, a struggle between different streams for supremacy set in, some streams being favored by shorter distance to the sea, or in having fewer or narrower hard strata to cross. As a result, the whole system of drainage has been modified. Regions of both folded and flat-lying rocks through uplift and erosion have been carved into mountain and valley, plateau and ravine. The final result is the surface of today, with flat-topped mountains cut by deep, picturesque water gaps, and deeply dissected areas of generally accordant upper level.

In the last minute of geologic time, as it were, ice which had been accumulating in Labrador and west of Hudson Bay, advanced to cover large areas in the northeastern and northwestern parts of the State, widening some valleys, filling others with debris, leaving a mantle of till over the whole surface, and forming moraines and other hilly deposits where the edge of the ice stood still for a time. Many changes in drainage occurred and when the ice melted and retreated, choked valleys created lakes, and streams diverted from their former channels often produced waterfalls.

Before we close, let us glimpse for a moment the history of living things as shown by the fossils in Pennsylvania's rocks. Had we no other proof of organic evolution, one could hardly fail to see the evidence of unfolding life even in our incomplete succession. The Precambrian rocks are devoid of fossils in Pennsylvania, but some marble of this age in Northampton County carries graphite (carbon) flakes. So far as we know, any considerable amount of this material can so occur only as a result of life processes, even though metamorphism has obliterated the original form and structure of the organisms. The Cambrian rocks contain the borings of such low organisms as "worms," and the remains of a few primitive shell fish and crustaceans. Higher types of these same kinds of animals occur in the Ordovician beds. Our Silurian rocks are crowded with a swarm of all sorts of marine invertebrates, and in Perry County actual remains of fish have been found, the oldest backboned animals in Pennsylvania so far recorded.

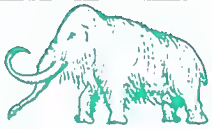
The Devonian rocks carry much the same kinds of fossils as do the Silurian, but fishes are commoner and many of the forms are more specialized. Amphibians left their bones and tracks in our "Carboniferous" strata in western Pennsylvania. The Triassic occasionally contains footprints of small, primitive dinosaurs. Finally, in cave deposits have been unearthed remains of Quaternary mammalian and bird bones which show a very different faunal assemblage from that of our present woodlands, for they include such beasts as the southern peccary and the wooly mammoth of the north. We find no satisfactory and accepted trace of man antedating the Indians, but as such remains are reported from other parts of North America, who knows when such may turn up in Pennsylvania?

No greater service to geology could be performed by the layman or amateur geologist than for him to call the attention of the professional geologist or paleontologist to such finds as he thinks worthwhile. The ancient land tracks of Devonian backboned animals just mentioned were found by a nonprofessional worker. What can you discover? The Pennsylvania Topographic and Geologic Survey at Harrisburg stands ready to help you and to answer your questions. Do not hesitate to use this service; it is freely at your disposal.

ADDITIONAL PENNSYLVANIA GEOLOGICAL SURVEY BOOKLETS

Educational Series 1—Rocks and Minerals
Educational Series 2—Common Fossils of Pennsylvania
Educational Series 3—Ground Water
Educational Series 5—Geology and the Gettysburg Campaign

GEOLOGIC TIME SCALE

	LIFE RECORD TYPICAL FOSSILS	ROCK RECORD PREDOMINANT ROCKS	GEOLOGIC NAMES PERIODS
1		Glacial deposits	QUATERNARY
		EROSION Sands & Clays	TERTIARY
65		EROSION Sands & Clays	CRETACEOUS
135		EROSION	JURASSIC
180		Shales & Sandstones Diabase intrusions	TRIASSIC
230		EROSION Shales, Sandstones, Coals, & Limestones	PERMIAN
280			PENNSYLVANIAN
310			MISSISSIPPIAN
350		Shales, Red beds, Sandstones, & Limestones	DEVONIAN
405			SILURIAN
425		Shales & Sandstones	ORDOVICIAN
500		Limestone & Dolomite Sandstone	CAMBRIAN
600	ALGAE	EROSION Granites, Gneisses, & Schists	PROTEROZOIC ERA
			ARCHEOZOIC ERA
4000+	ORIGIN	OF THE	EARTH